RESEARCH HIGHLIGHTS

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IMPROVED MAKE-UP AIR SUPPLY TECHNIQUES

The research described in this Research Highlight *was first published in 1989, but it has never been released in a summary form. This* Research Highlight *has been written for distribution now because the findings of the research project are still valid and can still contribute to the understanding of make-up air supply in residential buildings.*

Introduction

During normal operation of a house, air is exhausted by mechanical ventilation equipment (e.g., bathroom or kitchen fans) and through vented combustion devices (for example, furnaces or fireplaces). Air that is brought into the building to replace this exhausted air is called make-up air. Typically, houses depend on natural leakage through the building envelope for make-up air. However, as construction methods have improved and houses have become tighter, these natural leakage areas have become smaller. As a result, to produce the same amount of make-up air, exhaust devices must create larger negative pressure differences across the building envelope. One danger is that the negative pressures created by exhaust appliances could overcome the venting forces used to expel combustion exhaust gases, causing spillage of these combustion products into the house. The need for an effective system to introduce make-up air to the living space was becoming apparent.

This work was initiated to develop appropriate evaluation criteria for make-up air systems, to examine and test existing make-up air systems based on the identified criteria, and to develop an improved make-up air system to better meet the criteria.

Research program

In developing the evaluation criteria for make-up systems, a limit for house depressurization must be set to ensure the house functions safely with respect to spillage or backdrafting. Based on published spillage characteristics of naturally aspirating appliances, it was determined that for the majority of the existing housing stock to operate safely, a negative pressure limit of -5 Pa was reasonable. For house depressurization to remain under 5 Pa, make-up air flow would be required. Based on an evaluation of typical flow requirements for very tight and tight conventional houses, it was determined that the make-up air system must be capable of introducing at least 100 to 125 L/s of make-up air when required.

An opening through the building envelope is required for the make-up air to reach the living space. However, unless a mechanical driving force is used, the opening must be very large [>200 mm (8 in.)] to provide at least the minimum required flow (100 L/s) at the minimum pressure -5 Pa. One approach to providing a mechanical force is to use equipment already in the house, such as the furnace fan; however this approach can introduce some control problems. Another approach is to use a separate fan (however, no "specialized" make-up air fans were found in the course of the study).

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The make-up air unit should supply air on an as-needed basis, as continuous operation would result in a net positive pressure in the house, causing higher heating costs and exfiltration-related problems, such as condensation. Therefore, a flow control element, such as a damper or "constant flow regulator" is required. These can be activated manually, thermally, barometrically or electrically. In order to achieve a desired level of comfort, depending on the climate, airflow and level of mixing prior to introduction into the occupied space, it may be necessary to heat the make-up air.

Based on the evaluation of the requirements of a make-up air system, the following set of base criteria were developed to allow effective comparison and rating of make-up air equipment:

- Pressure control capability
- Required flow rates
- Distribution temperature
- Potential to withstand the elements (weather protection)
- Failure analysis (the hazard from failure of the device must be no higher than if no device was installed)
- Cost

For each of these categories, a 0 to 3 rating scale was developed and a weighted ranking assigned to each category. Products available on the market were then scored using the rating scale and the weighted ranking.

Research results

There was no integrated make-up air system on the market that addressed all make-up air needs. Rather, the products on the market were individual components of a make-up air system. However, to analyze the benefits of "make-up air products," it was necessary to examine their performance within an entire system. To do this, each device was evaluated as part of a "base system." Four types of base systems were defined:

1. Passive openings
2. Duct to return duct of a forced-air furnace
3. Duct with in-line supply fan and
4. Balanced fans (supply and exhaust)

The results of these systems evaluations at a pressure of -5 Pa are shown in Table 1. The systems were also evaluated at -15 Pa.

The results showed that that systems that are directly fan-driven are essentially pressure insensitive and their flow ratings are not affected by the difference in pressure limits. However, the same is not true of passive ducting and furnace draw systems. In order to achieve flows sufficient to compensate for a reasonable exhaust load, it may be necessary to use ducts as large as 200 mm x 350 mm (8 in. x 14 in.) to provide 150 L/s at -5 Pa. Most "make-up air devices" examined in this project were not even available in sizes equivalent to 200 mm (8 inch) diameter ducts but were generally much smaller. Another important issue found was that systems directly connected to the furnace return could lead to premature failure of heat exchangers due to the condensation and thermal shock from the large quantities of cold air being introduced into the furnace return.

As the available devices were seen as only piecemeal solutions to the make-up air issue, a prototype system was developed that was hoped would better address all issues as an integrated system. The key element of the prototype system was the pressure-activated control unit, which relied on a lightweight, slack diaphragm subject to interior house pressure on one side and averaged exterior pressures on the other. When the house is subject to relatively low negative pressures, there is a net flow into the volume directly below the diaphragm, which causes it to inflate. A light-emitting diode and photo sensitive transistor were used to detect displacement of the diaphragm, to signal control of the fan. The prototype make-up air system was installed in a typical house and testing was performed to evaluate the ability of the prototype to provide make-up air with respect to the design criteria. While this initial research showed some promise, subsequent efforts by CMHC to further the development of the slack diaphragm technique were not successful.

Implications for the housing industry

With the trend towards increasing the airtightness of the housing stock, the need for an effective system to introduce make-up air to the living space was becoming apparent. At the time this study was undertaken, there were no integrated make-up air systems on the market that addressed all make-up air needs. However, this study and other studies helped identify the limitations of air supply systems and have led to the increased use of spillage-resistant appliances.

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Table 1 - Analysis of Make-up Air Products/Systems at 5 Pa

System Description	Flow at ΔP 5 pascals	Pressure Control	Distribution Temperature	Weather Protection	Failure Analysis	Overall Rating	* Cost Capital	* Cost Operating	* Cost Amortized
Weighting	**0.25**	**0.25**	**0.2**	**0.15**	**0.15**		**$**	**$**	**$**
PASSIVE SYSTEM									
200 mm duct	FAIL					FAIL			
200x350 mm duct	2.5	2.4	1	1.5	2.5	2.03	200	100	130
200x350 mm with multiple triggered damper	2.5	2.3	1.5	2	2	2.10	475	30	101
As above with inlet heat	2.4	2.3	2.5	2	2.5	2.35	575	30	116
CONNECTED TO FURNACE RETURN									
150 mm duct	FAIL					FAIL			
200 mm duct	1.9	1.5	2	2.3	1	1.75	225	250	284
200 mm duct with combustion triggered electric damper	1.9	1.4	2.2	2.5	2	1.94	400	10	70
200 mm duct with multiple appliance triggering	1.9	1.9	2	2.5	2	2.03	475	50	121
As above with inlet heat	1.8	1.9	2.5	2.5	2.5	2.18	575	50	136
200 mm duct with a local barometric damper	1.8	1.6	2	2	1	1.70	300	200	245
200 mm duct thermally activated damper	1.9	1.2	2.3	1.5	1	1.61	300	0	45
IN-LINE FAN									
Direct to interior	2.5	1	1	2.5	1.5	1.68	325	355	404
To furnace return	2.5	1	2	2.7	2	1.98	350	350	403
To interior with inlet heat and multiple appliance triggering	2.5	2	2.5	2.8	2	2.35	575	50	136
As above to furnace return	2.5	2	3	2.8	2	2.45	600	50	140
BALANCED FAN									
Without heat recovery	2.3	1.8	1	2.5	2	1.90	1,000	350	500
HRV	2.3	1.8	2	2.5	2	2.10	2,000	- 50	250
HRV with appliance triggered damper on exhaust	2.3	2.3	2	2.5	2	2.23	2,200	- 50	280
As above with post heater	2.3	2.3	3	2.5	2	2.43	2,300	- 50	295

* Capital cost of supply and installation

Operating cost for maintenance and power, plus or minus auxiliary costs and credits

Amortized cost is operating cost plus simple amortization of capital cost per year, over 7 years

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Research Report: Improved Make-up Air Supply Techniques, 1989, 107 pages.

Research Consultant: Buchan, Lawton, Parent Ltd.

Housing Research at CMHC

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